BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 05050

SUBJECT: Sensitivity of the Viking Aeroshell and Scientific Payload to Knowledge of the Martian Atmosphere - Case 103-7

DATE: May 22, 1970

FROM: J. L. Blank

ABSTRACT

A tradeoff study shows that the level of uncertainty of the Martian atmosphere can have a marked effect on landed payload. Taking Viking as an example, if the minimum design Martian atmosphere were known more accurately, the Viking aeroshell diameter could be reduced. This is because the decelerating drag force is proportional to the atmospheric density and the aeroshell size. The corresponding saving in aeroshell weight could be translated into an increase in the scientific payload. For the presently proposed weight model, a 1% reduction in aeroshell weight can yield a 4% scientific payload weight increase. Reasonable estimates of the atmosphere suggest the landed science weight could be nearly doubled.

(NASA-CR-113354) SENSITIVITY OF THE VIKING AEROSHELL AND SCIENTIFIC PAYLOAD TO KNOWLEDGE OF THE MARTIAN ATMOSPHERE (Bellcomm, Inc.) 6 p

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MEMORANDUM FOR FILE

INTRODUCTION

A major component of the Viking atmosphere entry system is the aeroshell. As shown schematically in Figure 1, its function is to provide the initial deceleration of the surface lander, thereby reducing the velocity to a point where the ballute and chute systems can be utilized. The entry profile must be designed for the most adverse conditions. With respect to the aeroshell, this corresponds to designing for a minimum density model of the atmosphere, since the drag force along the entry trajectory varies as the density. Thus a smaller aeroshell suffices to produce the same deceleration in a denser atmosphere. We consider here the possible increase in scientific payload weight obtainable if, upon improving our knowledge of the Martian atmosphere, the aeroshell can be designed for a denser atmosphere than is presently considered safe.

A Viking working weight model(1) fixes the total lander weight after bioshell separation and deorbiting at 1,860 lb. The weight of the aeroshell, including the heat shield and wire harnessing, is 320 lb, while the scheduled weight for the landed science package is 75 lb. Thus a 1% reduction in aeroshell weight may be translated into a 4% increase in the landed science weight. Moreover, such a possible weight shift is a small fraction of the total lander weight, so an aeroshell-science package tradeoff can be performed without significant impact on the rest of the lander.

AEROSHELL SENSITIVITY

To illustrate the sensitivity of the Viking aeroshell to our knowledge of the Martian atmosphere, we consider a simple model for the aeroshell phase of the entry profile. After lander separation and deorbit operation, the lander of mass M enters the Martian atmosphere at an altitude H_E, entry angle γ_E, and entry speed V_E. For our model, we demand that, given any design atmosphere, pilot chute or balute deployment occurs at an altitude H_B where the lander speed is fixed at V_B. For simplicity we assume that the aeroshell has zero lift.* Since the drag force on the aeroshell is much greater than the gravitational force on the lander, the entry trajectory for the aeroshell phase is adequately represented by a straight line. The equation of motion for the lander during this phase is

$$M\ dV/dt = F_D = -C_D \frac{1}{2} \rho A V^2 \qquad (1)$$

where V is the lander velocity, F_D the drag force, C_D the drag coefficient, ρ the atmospheric density, and A the projected aeroshell area on a plane normal to $\underline{V}$. For a fixed aeroshell shape at hypersonic speeds, pressure drag is the dominant drag force and C_D can be assumed constant. If we define the altitude H by $dH = V \sin \gamma_E\ dt$ and the atmospheric pressure p by $p = \int_{\infty}^{H} \rho g dH'$, then the solution of (1) can be written as

$$V = V_E \exp\ (-p/2\Delta g \sin\gamma_E) \qquad (2)$$

Here $\Delta = M/C_D A$ is the ballistic parameter and g the gravitational acceleration. This result is for a general, planar atmosphere.

By use of (2), we can calculate the aeroshell area required to decelerate the lander to the velocity V_B at the altitude H_B, where the pilot chute or ballute is deployed. We suppose that the design atmospheric pressure is p_1 at the altitude H_B, and that p_1 corresponds to the present 99% confidence level for the Martian atmosphere. If, at some future date, our knowledge of the Martian atmosphere is improved, we should be able to scale-down the aeroshell and still decelerate the lander to the velocity V_B at the altitude H_B where the 99% confidence level for the pressure is now $p_2 > p_1$. The potential aeroshell weight saving can be computed from (2) and we find

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*The entry profile depicted in Figure 1 is for a zero lift aeroshell. The current, revised aeroshell design calls for a lift-to-drag coefficient ratio of 0.135. By allowing for aeroshell lift, the balute can be replaced by a pilot chute whose function is to deploy the main chute.[1]

$$\frac{m_2}{m_1} = \frac{A_2}{A_1} = \frac{p_1}{p_2} \qquad (3)$$

where m_1 and m_2 are the masses of the aeroshells designed for the atmospheric pressures p_1 and p_2, respectively. We have assumed that the aeroshell mass is directly proportional to its projected area.

We can illustrate potential aeroshell weight savings using (3). Let the subscript 1 refer to the current design. The model Martian atmosphere assumed for aerodynamic loading and heating purposes is a minimum scale height atmosphere.(2) For this model, the surface pressure is 4 mb and pilot chute deployment occurs at an altitude H_B = 30,000 ft where the Mach number is 2.2 and the dynamic pressure is 10 psf. This corresponds to an atmospheric pressure of p_1 = 1.4 mb at 30,000 ft.(2)

Presently, the Mars surface pressure is thought to be 5.5 mb with a scale height of 15 km. The minimum scale height atmosphere is a conservative one for designing the aeroshell. If the design atmospheric pressure at 30,000 ft could be raised 20% to p_2 = 1.7 mb, the separable aeroshell weight could be reduced from 320 lb to 264 lb. This would be obtained by reducing the aeroshell diameter by 1 ft from its present value of 11.5 ft. The 56 lb weight saving would then be available to expand the scientific payload.

For the given example, the increase in design pressure from 1.4 mb to 1.7 mb at 30,000 ft can safely be made using our present knowledge of the Martian atmosphere. The suggested modification in aeroshell size and weight, however, requires further considerations to ascertain compatibility with the design and engineering interfaces of the rest of the Viking lander.

CONCLUDING REMARKS

The proposed Viking aeroshell and landed science package weights are both small compared to that of the rest of the Viking lander. Thus if we view weight as the only criterion, a tradeoff between these two components should not seriously alter the other system designs. However, other criteria, both design and managerial, must be considered. For example, packaging and system integrating modifications would most likely be required if a 10-20% reduction in aeroshell size was desired. On the other hand, no significant changes should be necessary to maintain adequate heat shielding or structural integrity of the aeroshell.

The size and, therefore, weight of the aeroshell are dependent upon the model Martian atmosphere which must be designed for. If our knowledge of the Mars atmosphere were improved so that the lower bound on the surface pressure were raised, the Viking aeroshell could be reduced in size. The resulting weight saving may be used to increase the science payload. If such a tradeoff is not prohibited by other considerations, a doubling of the landed science weight is a plausible expectation from a modest improvement in our knowledge of the Martian atmosphere. This is an important instance where an apparently small residual uncertainty in environmental design criteria has a potentially large effect on mission performance.

J. L. Blank

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Attachments
References
Figure 1

REFERENCES

1. J. Timmons, personal communication, May 1970.

2. Viking 75 Project Report M75-125-0, "Mars Engineering Model", Langley Research Center, March 1970.

3. Viking Project Report M73-115-0, "Viking Description Presentation at Viking Preproposal Briefing", Langley Research Center, September 1969.

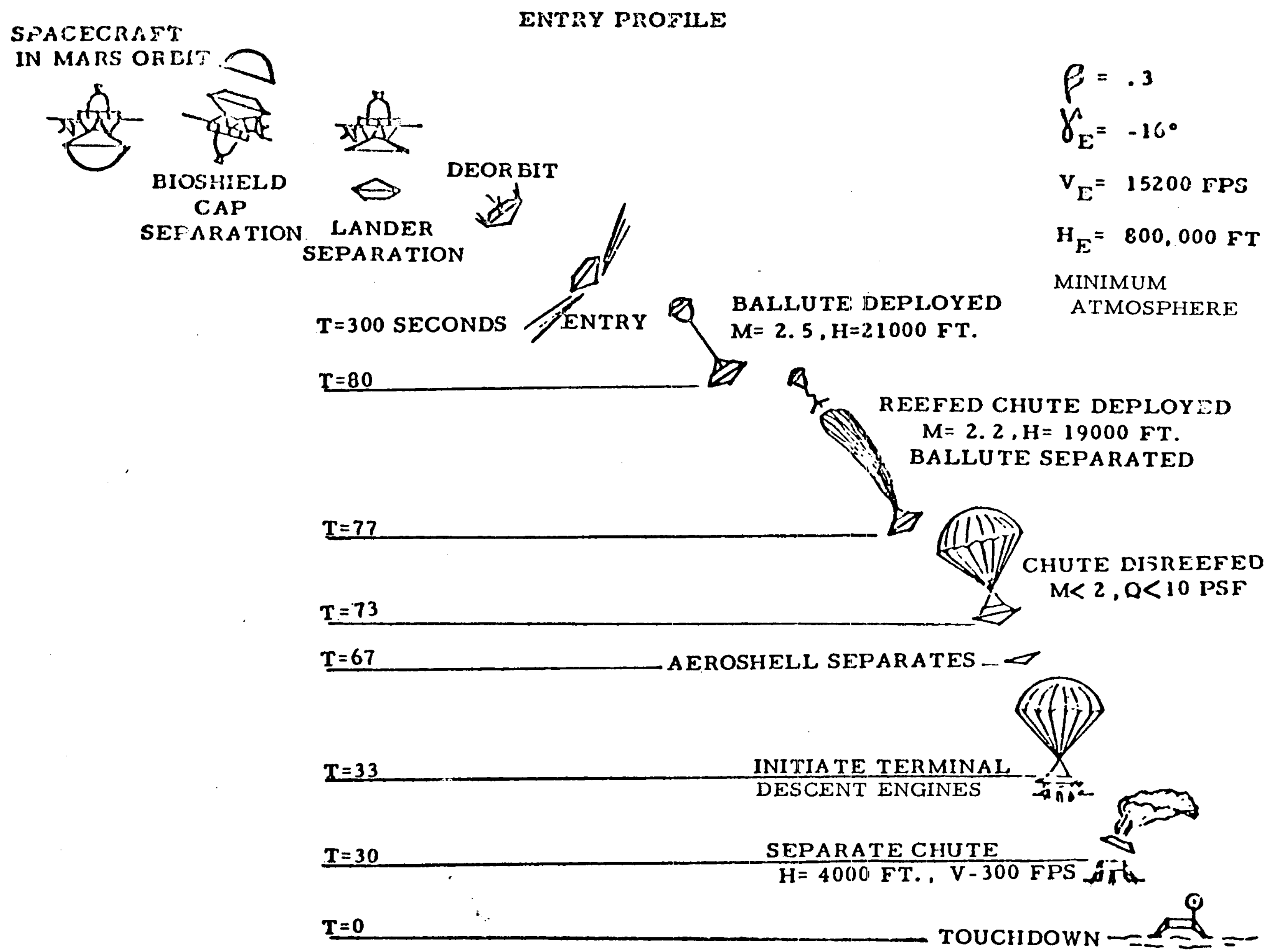

Figure 1 (from Reference 3)

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